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## THE HABITS OF CAMBARUS.

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It is the purpose of the present paper <sup>1</sup> to present in a brief way some of the main points which have been collected on the habits and distribution of North American crayfishes.

Our crayfishes offer a particularly inviting and important field for ecological work. A fuller knowledge of the habits of the different species may contribute to a more complete understanding of the very remarkable sexual dimorphism occurring in the adult males. Individual variability in the species of *Cambarus* is very great and puzzling, and the differentiation into species as compared with the other genus *Astacus*, of the subfamily to which it belongs is extensive. The great differences in environment to which the species are subjected is apparent to anyone who is acquainted with the physiographic conditions prevailing in the vast stretch of territory over which this genus is distributed and an examination of these conditions and the adaptation of the animals to them would doubtless yield interesting results.

The habits of any species necessarily depend largely upon the character of its environment, and from an ecological or biological standpoint it is impossible to consider the two separately. In this place space cannot be given to a discussion of the importance of a correlation of physiographic features with floral and faunal distribution as it has been emphasized by Woodworth, Hays and Campbell, Simpson, Cowles, Adams and others.

It has long been known that the fishes occurring in the upper course of a stream of considerable size are different from those found in its lower course, and more recently the ecological factors concerned have been more fully discussed. In the crayfishes as in fishes the Fauna of different parts of a stream is not the same,

<sup>1</sup> This is an abstract of a part of an ecological catalogue of the crayfishes belonging to the genus *Cambarus* which is being published in the *Kansas University Science Bulletin*.

but in the crayfishes the problem is not a simple one since the animals may remain out of water for a considerable length of time and it is to be expected that the conditions under which they may be found are not always the same. *C. virilis* usually occurs in running streams but may also be found in stagnant ponds with *C. immunis* and *C. gracilis* and has been known to resort to burrowing. *C. bartonii* seems to be characteristic of the cooler mountain springs and streams, but it is also found in limestone caves with *C. pellucidus* and associated with *C. diogenes*, a burrowing species, with the same habits. *C. affinis* and *C. blandingii* may also be used as illustrations of the same point.

While an examination of a table of distribution of species offers some interesting suggestions, it is as yet impossible to prepare a list of species characteristic of certain types of localities, though many species may be accurately assigned.

Several species appear to be confined to mountain streams. The crayfishes of the Ozark Mountains are little known, but the point is illustrated in the Appalachian tributaries of streams emptying into the Atlantic Ocean and the Gulf of Mexico. The lower courses of these streams are very different from their sources and the general Fauna is very different. *C. extraneus*, *C. spinosus*, *C. bartonii*, *C. acuminatus*, *C. forceps*, *C. longulus* and other species seem to be confined for the most part to mountain streams. As is the case in fishes, the same species may occur in the head waters of streams originating on opposite sides of a divide and debouching at widely separated points. Some species found in the lowland portions of the same streams are characteristic so far as yet known, and some idea of the species characteristic of the lower portions of the course of a stream — the lowland forms — may be gained from an examination of a list of the forms reported from the Atlantic coast plain and the lower portions of the Gulf States. It must be remembered, however, that elevation above the sea is not the only factor producing lowland conditions so far as faunal and floral distribution is concerned.

Faxon pointed out that the greater the fall of a stream the greater the difference between the species of the upper and lower portion of its course and while the question needs careful

investigation the same seems to be true of the number of species found in a given stream ; a river with a heavy fall having a larger number of species than one with the same or greater length, but having a more limited vertical range. It is apparent that the former would present much more diverse life conditions than the latter.

The habits of certain of the North American species of crayfishes have attracted considerable attention. These are the burrowing species. As burrowing species are to be designated only those forms which show an especial dependence upon this method of life, since it is reasonable to suppose that most, if not all the stream-inhabiting species dig short burrows in the banks at least in certain localities. The species which seem to be most dependent on this habit are *C. diogenes*, *C. gracilis*, *C. carolinus*, *C. argillicola*, *C. simulans* and *C. immunis*.

*C. diogenes* has well been characterized as preëminently a burrowing species. Its presence is usually indicated in the low places where it is most frequently found by the large number of mud "chimneys," about a foot in height, sometimes scattered over several acres, radiating from some sluggish stream, ditch, brook or lower, moister portion of the area, the animals being frequently found at a considerable distance from any permanent body of water. Of the other species *C. gracilis* seems to be as typically a burrowing species as *C. diogenes*, and is generally reported as an inhabitant of prairie regions. Adults are to be found in open ponds only in the early spring, and the burrows are often found at long distance from any permanent body of water. *C. simulans* has been reported from streams and ponds and from burrows in a slough. *C. immunis* is known principally from stagnant ponds, resorting to burrowing upon the drying up of the ponds and upon the approach of winter. Of *C. argillicola* and *C. carolinus* the nature of the habitat has not been described.

All of the above are known to be "chimney-building" species. The "chimney," very aptly so called, is a mound of mud of a quite regular, conical or pyramidal form constructed at the mouth of the burrow, with a smooth, internal opening which is merely a continuation of the shaft of the burrow, and is sometimes sealed at the top. The chimneys of all the species have

not been carefully described, but so far as known they are essentially the same. That of *C. diogenes* has a maximum height of twelve inches, but is usually lower, is in shape, like a truncated cone often somewhat higher than broad. The most remarkable difference being that of chimneys two inches in diameter and eight to eleven inches in height, described by Abbott, who states that those found in meadows at a distance from running water were invariably broader and not so high as those erected near running water. The chimney is composed of pellets of clay firmly cemented together, owing to the moist condition in which they are laid on, giving an irregular, nodular appearance to the outside of the structure. This brief description applies to the more perfectly formed or typical chimney. We will recur to this subject later, after the form of the burrow has been mentioned. The actual process of construction has been observed only once.

As has been suggested above, where the habits of the different forms was mentioned, the burrows are made at the time of the drying up or the lowering of the body of water in which the animals are found. At the edge the burrow may be a simple shaft, a foot, more or less, in depth, ending below in a cistern-shaped enlargement, in which the animal, usually only one but sometimes two, is found. Farther back from the stream in moist meadows where the burrows may have been begun at the time of high water, the depth must necessarily be much greater to reach soil water during the prolonged heat of summer. These burrows are not uniform in structure but as yet data are lacking for the determination of any plan, other than the one of reaching water in the most direct manner. The presence of more than one opening to the same burrow has often been noticed. They are usually quite simple but occasionally are branched in various ways. When many burrows occur in a limited area they may easily become connected accidentally. Enlargements in the shaft of the burrow have been noticed and attributed to the original enlargement at the bottom of the burrow which has been repeatedly carried deeper as the water in the soil became lower. In recent observations on *C. carolinus* this explanation does not seem to hold.

Too much importance, it seems to me, has been attributed to the chimney in discussions of the habits of *Cambarus*. While the chimney is usually a very regular and well-built structure, it is often found, in some species at least, as a more or less irregular heap of clay pellets, and so far as our present knowledge extends, can hardly be regarded as anything more than the result of the easiest method of disposing of the material removed in excavating the burrow. On this point, however, further observations are desirable. The purpose of the sealing of the burrow is not so clear. The prevention of material falling into the burrow from the surface and possibly (?) protection against enemies may account for it. That the sealing is not a matter of the accidental falling together of the upper edges of the chimney while in a moist condition is evident from the fact that the opening is sometimes filled to below the surface of the ground and, as sometimes happens, with clay of a different nature from that composing the rest of the chimney.

Concerning the purpose of burrowing there can now be no question. Some species of *Cambarus* seem never to resort to the habit, in the restricted interpretation of the term, while others, *C. immunis*, and, to a less extent, *C. virilis*, are inhabitants of ponds or streams and resort to burrowing only upon the drying up of the ponds or the approach of winter, while *C. diogenes* and *C. gracilis* have adopted this mode of life almost entirely, being found in the open water during but a very small part of the year. That the burrows are not for retreats while the eggs are being hatched has been conclusively shown. That they serve as a place of protection against enemies has been suggested and while it cannot be stated that the burrowing species are not better protected against animal enemies than are the forms inhabiting open water this cannot be the primary purpose of the burrow. The burrows are almost invariably described as extending to the water in the soil, and while the water in the enlargement at the bottom of the burrow is usually very muddy, it enables the animal to keep its gills moist. A point of interest in connection with the burrowing species is the range of the species. *C. diogenes* seems to be the most widely distributed species. *C. argillicola* has a wide distribution, and *C. carolinus*

has been reported from widely separated localities. To what extent this is dependent on the habits of the animals is difficult to say, but the burrowing species obviously have a great advantage over the others in their ability to occupy territory which would be habitable to many of the species for but a very small portion of the year.

Only one species is found in salt water, *C. uhleri*, a species of limited range, is found in salt marshes covered twice daily by the tide, and also in brackish and fresh water where *C. blandingii* is sometimes found associated with it. *C. montezumæ* is said to occur in salt water.

Many observations have been made upon the blind species, inhabiting caves and underground streams in Kentucky, Tennessee, Indiana, Missouri and Florida, but they are not of a nature to be easily summarized. The blind forms are not confined to one group or section of the genus. The species are: *C. acherontis*, *C. setosus*, *C. hamulatus*, *C. pellucidus* and *C. pellucidus testii*.

Parasites, various species of Branchiobdella, have been noticed on *C. affinis*, *C. bartonii*, *C. digueti* and *Cambarus* sp. and will doubtless be found on many other forms, and *C. digueti* is recorded as being attacked by *Temnocephala*.

Little has been recorded of the habits of the crayfishes during the winter. It seems most probable that the stream inhabiting species pass the winter in burrows in the bank or under stones, etc., in the bed of the stream. The latter is sometimes the case with *C. virilis*. The burrowing species seem quite generally to spend the winter in the burrows, coming out early in the spring and returning again when the water begins to become low as the summer progresses.

Observations have been made on the colors of the crayfish in relation to its environment. One observer, working, for the most part, on *C. immunis*, with fewer observations on *C. propinquus*, *C. bartonii* and *C. diogenes*, concludes that the coloring closely resembles the environment and has a protective function. According to him, the colors in all cases were similar to the environment except in those with a red coloration. The red color, he concludes, is due to the immediate effect of the sunlight.

He found that young crayfishes which are red, due to the presence of large chromatophores, changed to blue or black or suffered no change as the adults of the locality were blue, black or red. He finds that the burrowing crayfish, *C. diogenes*, comes out in the spring much the color of the soil, but this color is gradually changed to red in the open sunlight. Other observations indicate that in the case of *C. gracilis*, as typically a burrowing species as *C. diogenes*, the females are always olive-green no change taking place during the time they are to be found in the ponds in the spring, while the few males which have been taken are a marked salmon red, although they had just left the burrow. In *C. carolinus*, another burrowing species, "red" and "blue" individuals seem to occur. While it is undoubtedly true that individuals of a species taken from different localities may show marked differences in coloration, caution must be exercised in designating all the differences as protective adaptations.

Observations on the breeding habits are very limited. As to the time of copulation and oviposition a few data have been recorded. In *C. diogenes*, upon the habits of which more has been written than any other species, copulation and oviposition seem to occur in the spring. One observer found females in burrows carrying eggs in March and April, while another gives the middle of May as the approximate time of hatching of the eggs. Another observed *C. diogenes* and *C. gracilis*, kept in aquaria, copulating in the spring and never found crayfishes (sp?) mating except in March, April and sometimes May, and was able to get reports of females "in berry" later than June in only two instances. Another observer reports the species as copulating in the open water April 2nd and laying eggs April 18th to 30th. A female with eggs in an early stage of development has been reported May 3rd. These observations were made over a wide range of territory. An interesting exception is the taking of a female with eggs nearly ready to hatch, on January 1st and might suggest autumn oviposition, as has been observed in some other species. Females of *C. gracilis* have sometimes been found in open ponds in early spring with a few young and it may be that the young leave the parent immedi-



ately after they quit the burrows in the spring. In southern Kansas, *C. simulans* has been taken from burrows, with eggs apparently recently laid, late in August, and in New Mexico, with the swimmerets loaded with eggs, in May. In *C. immunis* the females are found with eggs in stagnant ponds in the fall ; they pass the winter in burrows and appear again in ponds, where the process of hatching is completed, in the early spring — about March 21st. *C. argillicola* has been reported with young as early as April 2nd. *C. neglectus* was found with eggs and young in the cold water at the mouth of a large limestone cave in the Ozarks early in June, and since those taken at the same time in various other places in the neighborhood had neither eggs nor young, the lateness of the date may be attributed to the retarding effect of the low temperature upon the hatching of the eggs. In another locality *C. neglectus* (?) was taken with eggs April 13th. In *C. virilis* the females are found with eggs in the spring, but not during the winter.

Of the above species *C. diogenes* and *C. gracilis* are preëminently burrowing forms, *C. argillicola* is a burrower, *C. simulans* burrows extensively as does also *C. immunis*, and *C. virilis* sometimes resorts to the habit. *C. neglectus* seems to be found principally, in clear rocky streams. In regard to the burrowing species it has been suggested that the burrow is designed as a retreat while the eggs are being hatched, but this is not very likely, although the eggs may undergo a very large part of their development in the burrow.

Observations on the habits of the young crayfish are few. Two suggestive ones are that in *C. diogenes* the neatest chimneys are those constructed by the smallest individuals and that the young of *C. gracilis* are the first to appear in the stagnant ponds which are frequented by this species in early spring and are also found there in the late summer after other forms, *C. immunis*, *C. virilis*, and the adults of *C. gracilis*, have gone into their burrows.

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